The 2nd International Conference on
Countermeasures to Urban Heat Islands
Berkeley, California

Evaluation of Solar Reflectance of Cool Materials by On-site Measurement and its Aged Deterioration

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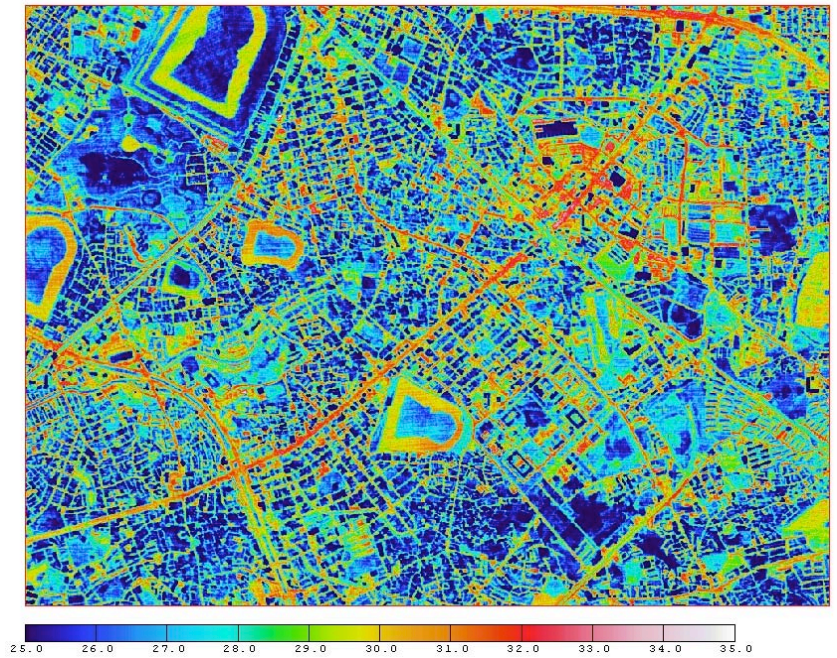
September 21, 2009

Building Exterior covered with Highly Reflective (Cool) Material

Countermeasure to Heat Island Phenomenon

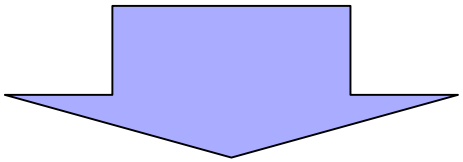
Control of Solar Absorption to Building Structure with Cool Material



- Decrease in Sensible Heat Transfer towards Outdoor Atmosphere (Decrease of Air Temperature)
- Decrease in Cooling Load (Decrease of Anthropogenic Heat)

Study Outline

Establishment of technique for evaluating Radiative Performance of Cool Materials (Cool Painting and Cool Waterproof Sheet)



On-site Measurement of Solar Reflectance

- Establishment of Measurement Method
- Discussion on Measurement Error Factor
- Evaluation of Aged Deterioration through long term measurement at the same sites

Measurement of Solar Reflectance

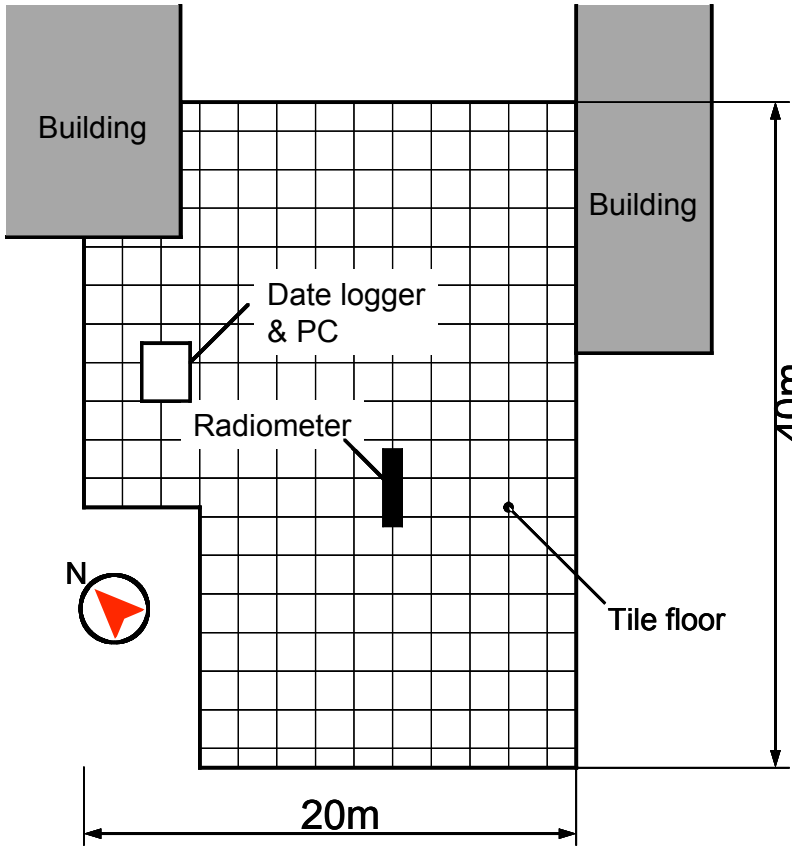
Case (1) Wide Measured Surface

$$\rho_m = \frac{S_\uparrow}{S_\downarrow}$$

- Total (wavelength)
- Diffuse

Solar reflectance ρ_m is obtained from the ratio between irradiated solar energy $S_\downarrow$ and reflected solar energy $S_\uparrow$ measured by radiometer.

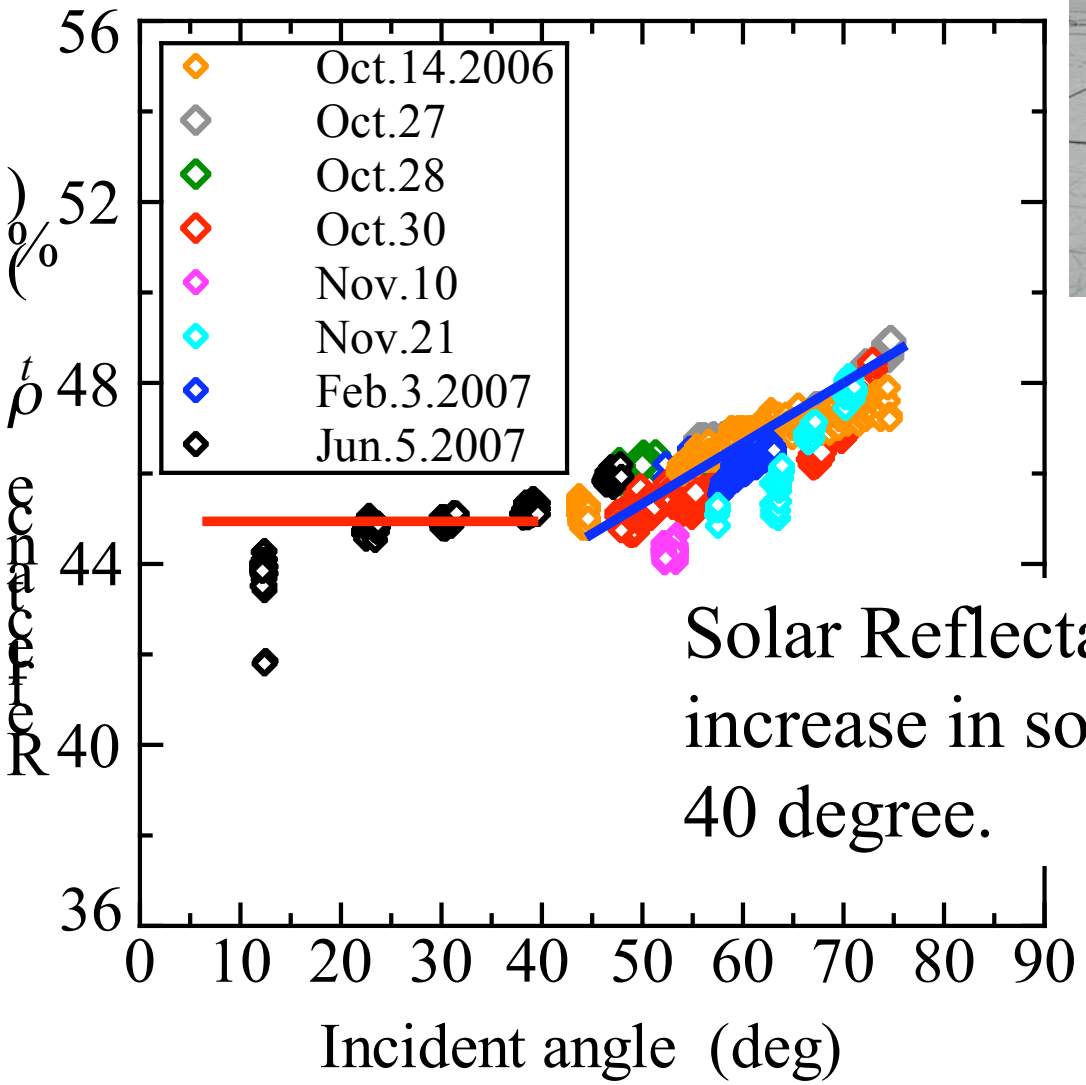
Open Terrace
covered with Tile



$$\rho_t = \frac{S_\uparrow}{S_\downarrow}$$

- Measured Site
  Osaka Prefecture Univ.
- Measured Date
  (2006)
  October 14, 27, 28 & 30
  November 10 & 21
  (2007)
  February 4 & June 5
- Measured Height
  40cm

Measured Results

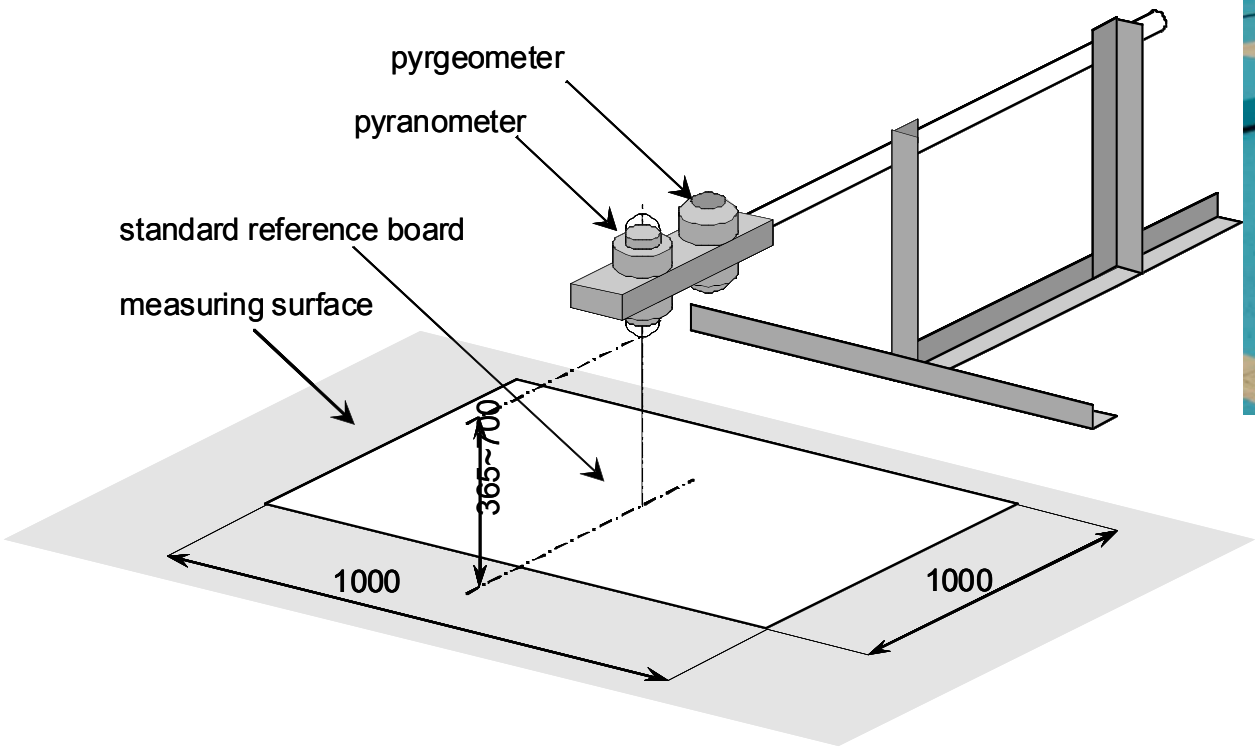


Specular reflection

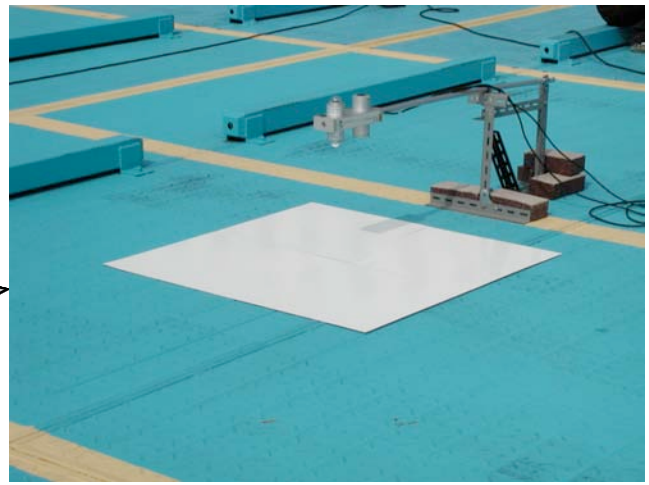
Solar Reflectance increases with increase in solar incident angle over 40 degree.

Case (2) Narrow Measured Surface

Measured value includes Influence of Reflection from Surrounding Surface → Use of Standard Reference Board with known Solar Reflectance



Measurement apparatus



Measurement State

Wavelength Region
305～2800nm

Measurement Method (A) for Solar Reflectance

Removal of Reflection Influence from Surrounding Surface by use of Single Standard Reference Board (white or black)

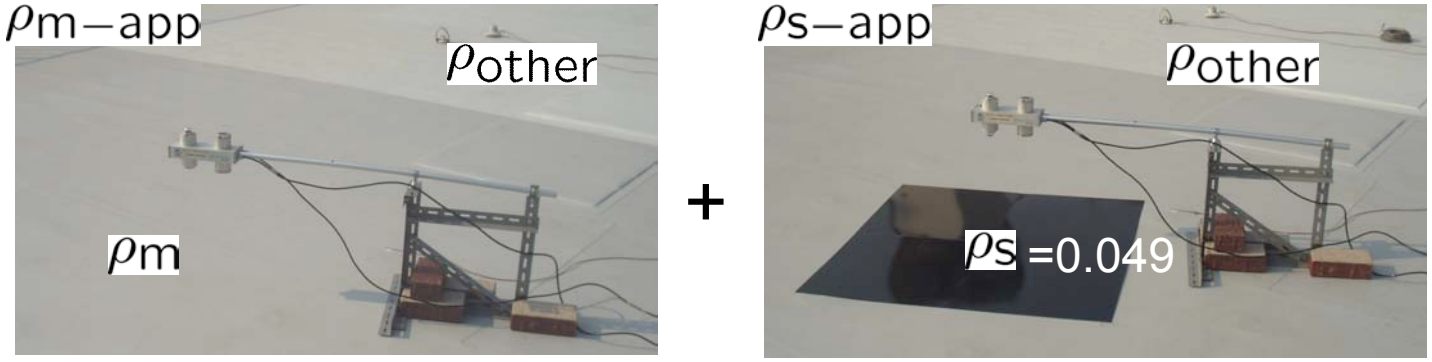
$$\rho_{m-app} = \phi \cdot \rho_m + (1-\phi) \cdot \rho_{other}$$

$$\rho_{s-app} = \phi \cdot \rho_s + (1-\phi) \cdot \rho_{other}$$

$$\Downarrow$$

$$\rho_m = \rho_s - \frac{\rho_{s-app} - \rho_{m-app}}{\phi}$$

ϕ : Geometrical factor



Apparent solar reflectance with and without standard board are measured, and real reflectance is calculated by using ϕ and ρ_s.

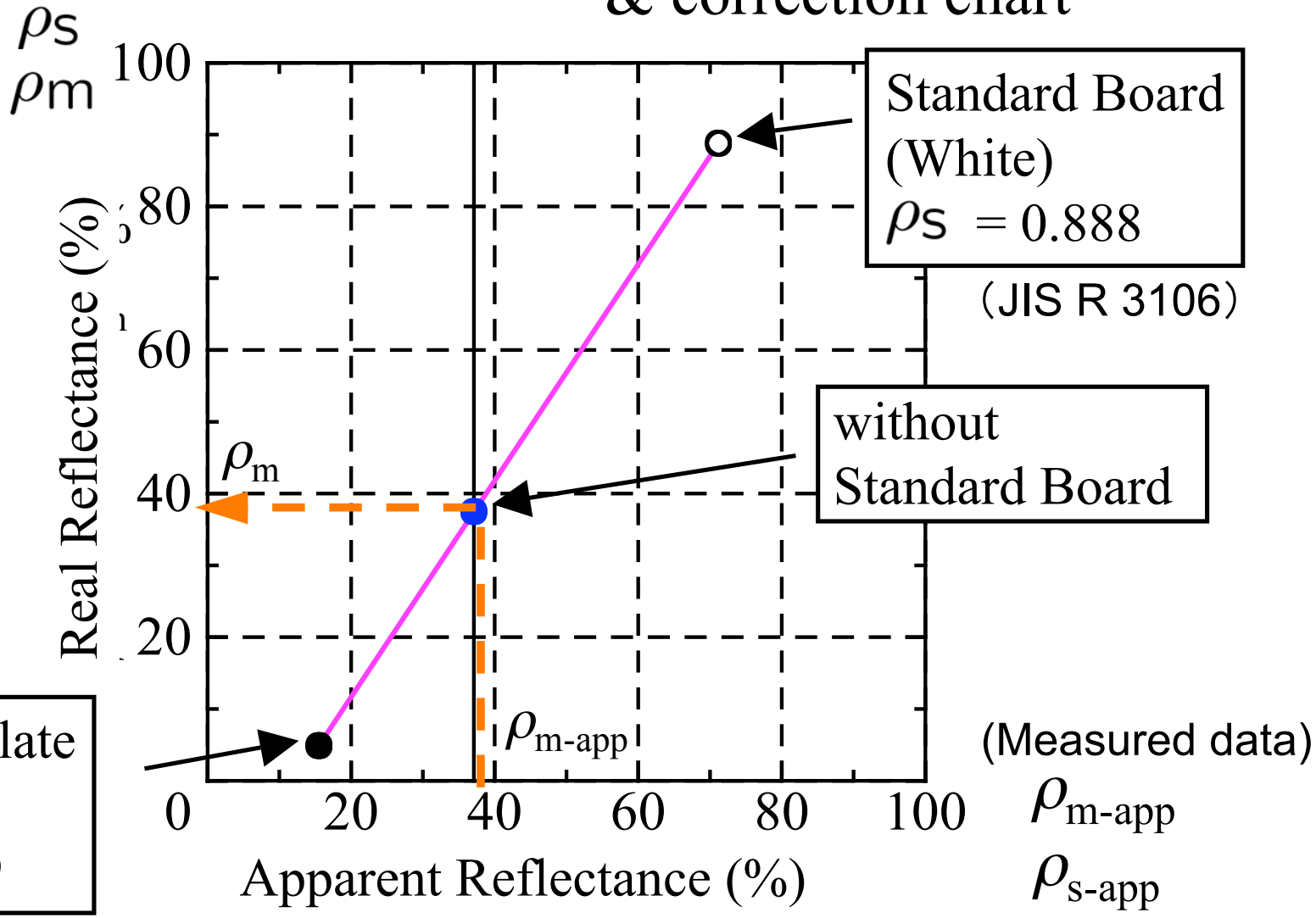
Measurement Method (B) for Solar Reflectance

(two points correction method)— two standard boards & correction chart

+

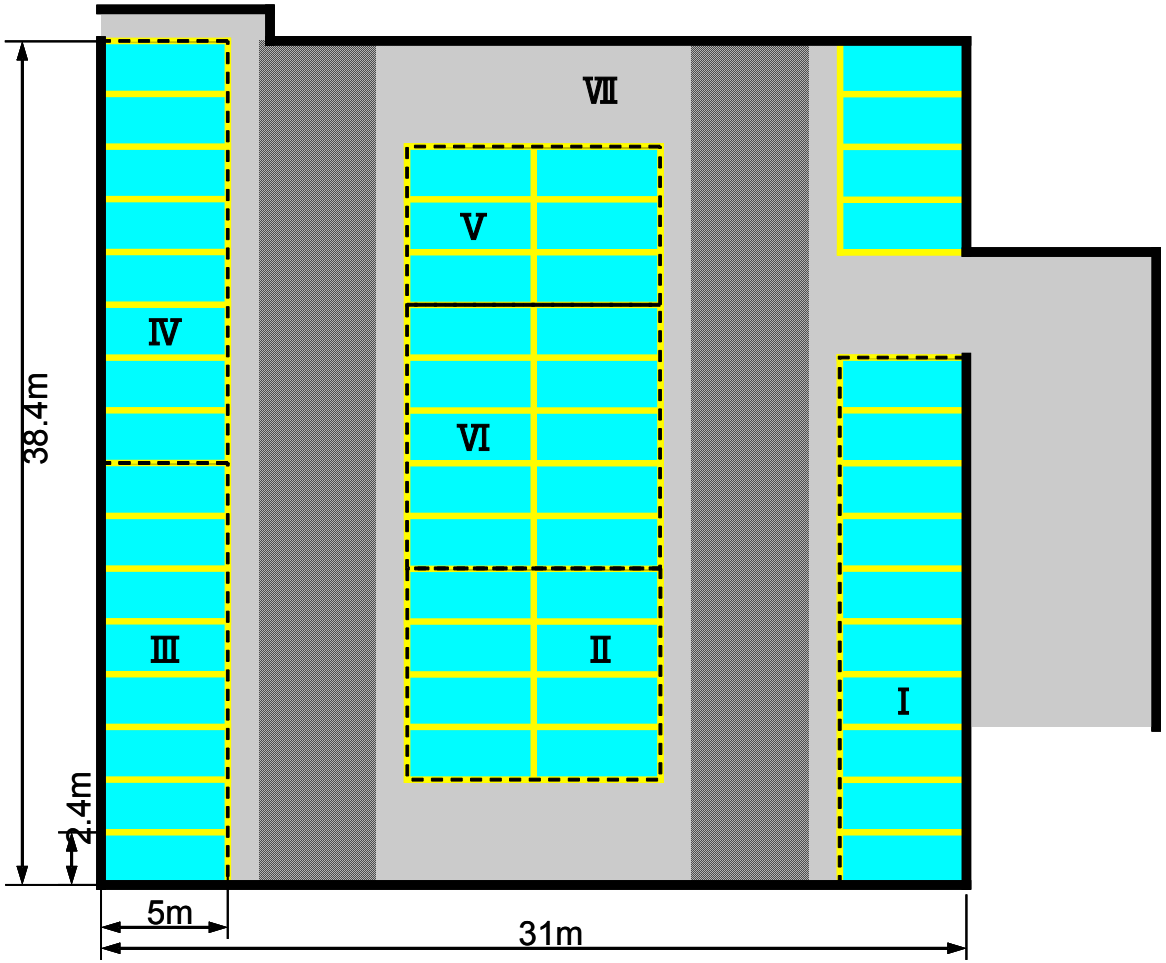
+

Standard Plate
(Black)
$\rho_S = 0.049$



Measurement Site (1): Cool Painting

(6 Companies)



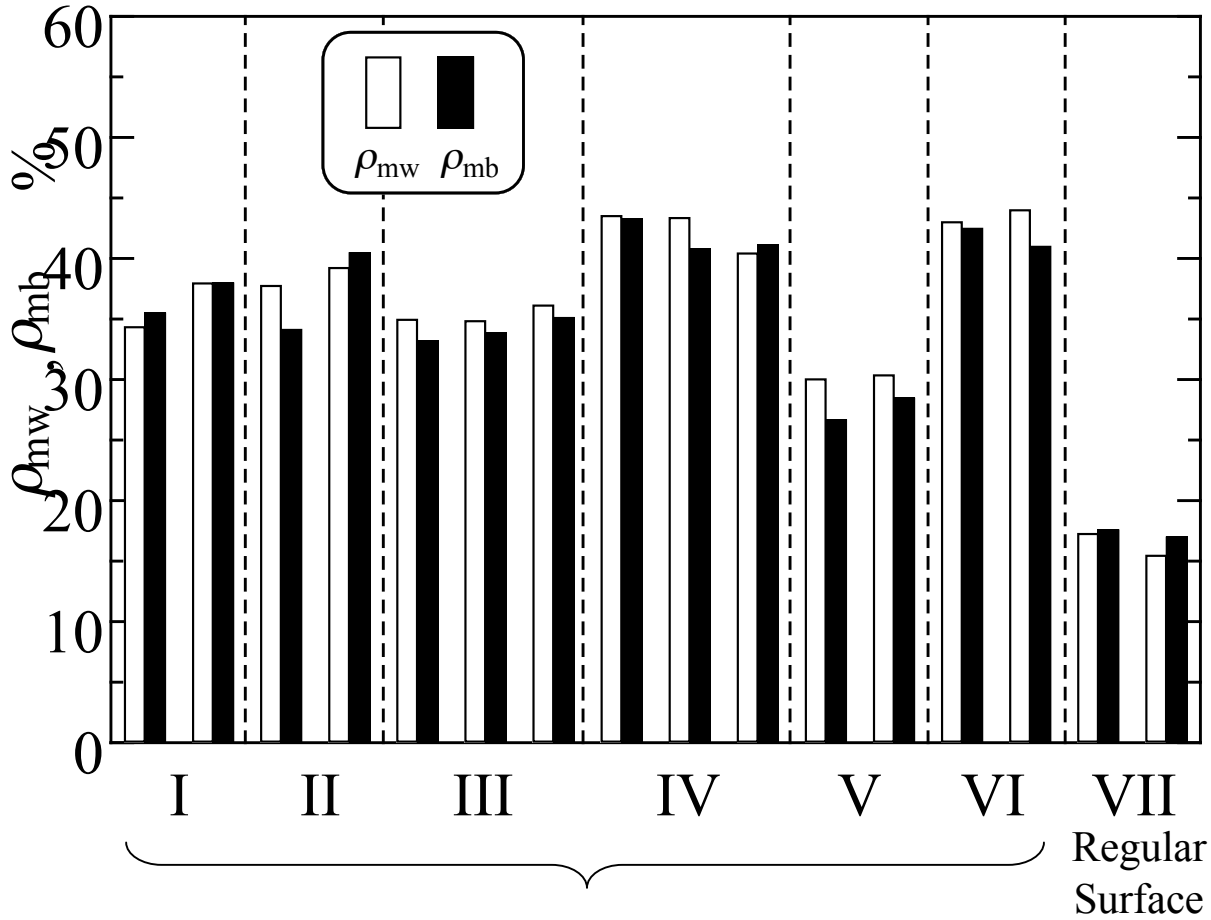
Outline of Measurement Site

(Parking Lot)

Measurement Situation

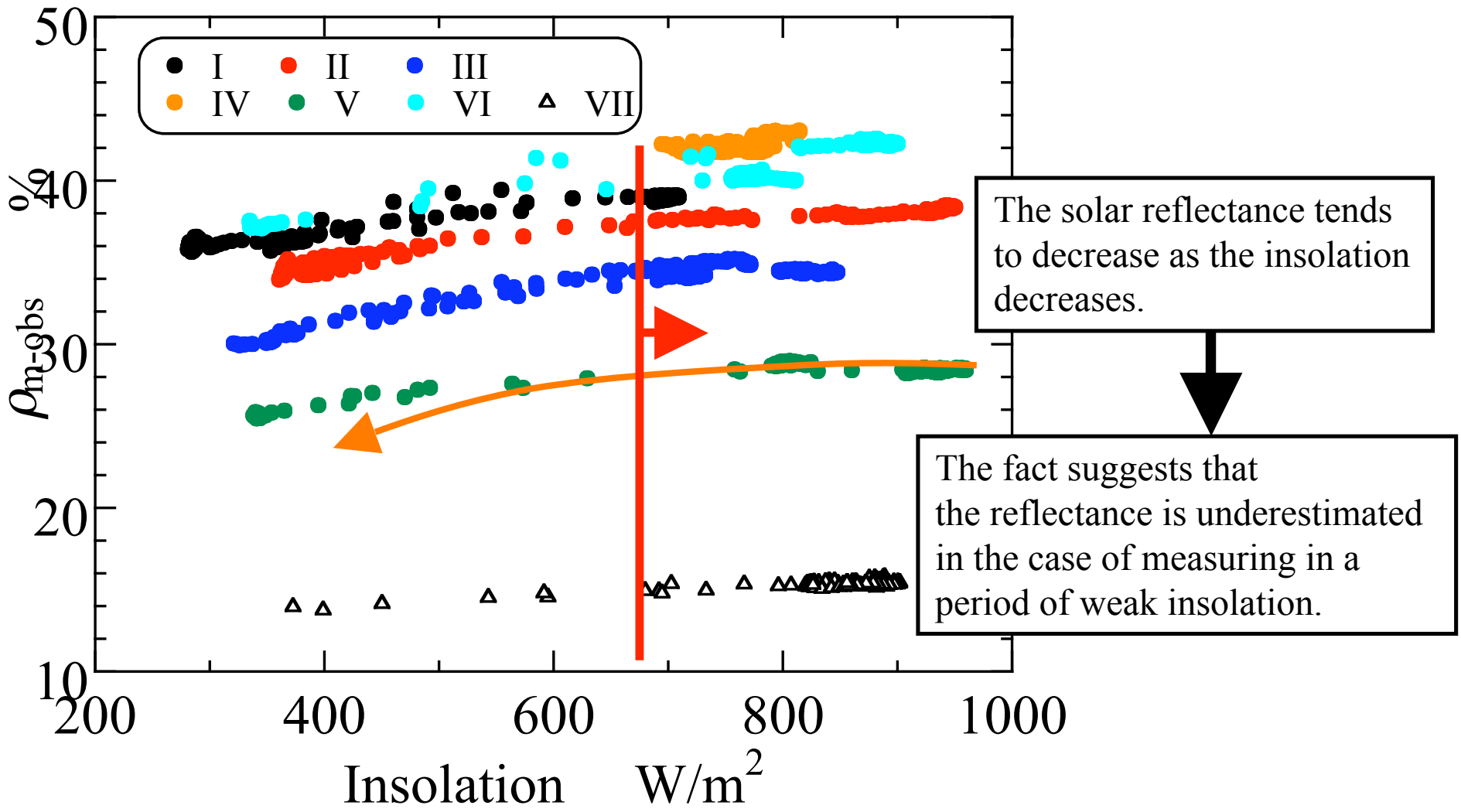
Measured Results (1)

- Measured Date: August 6, 2008

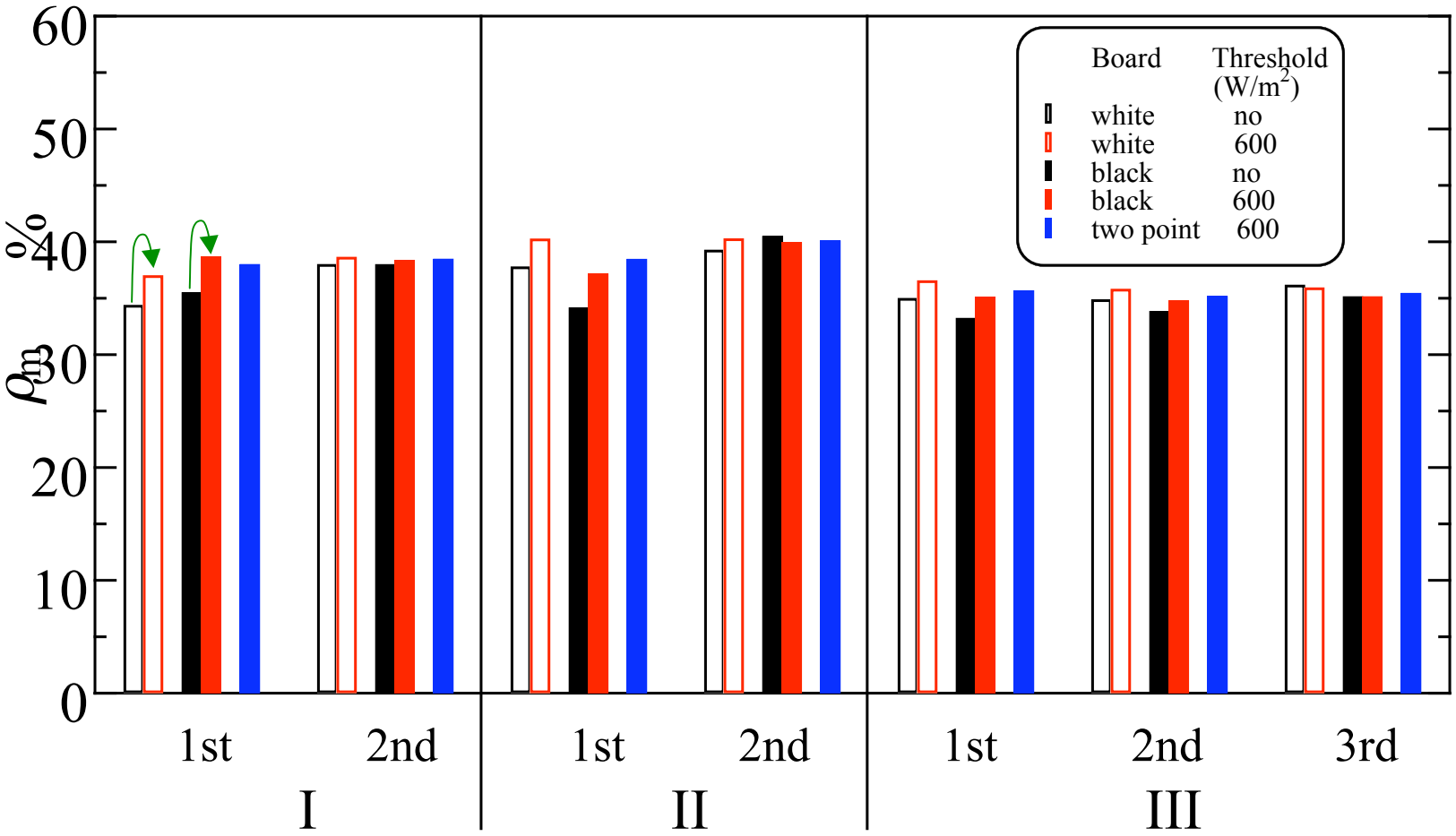


Dispersion of measured values are approximately 1.5%.

Accuracy of Measurement



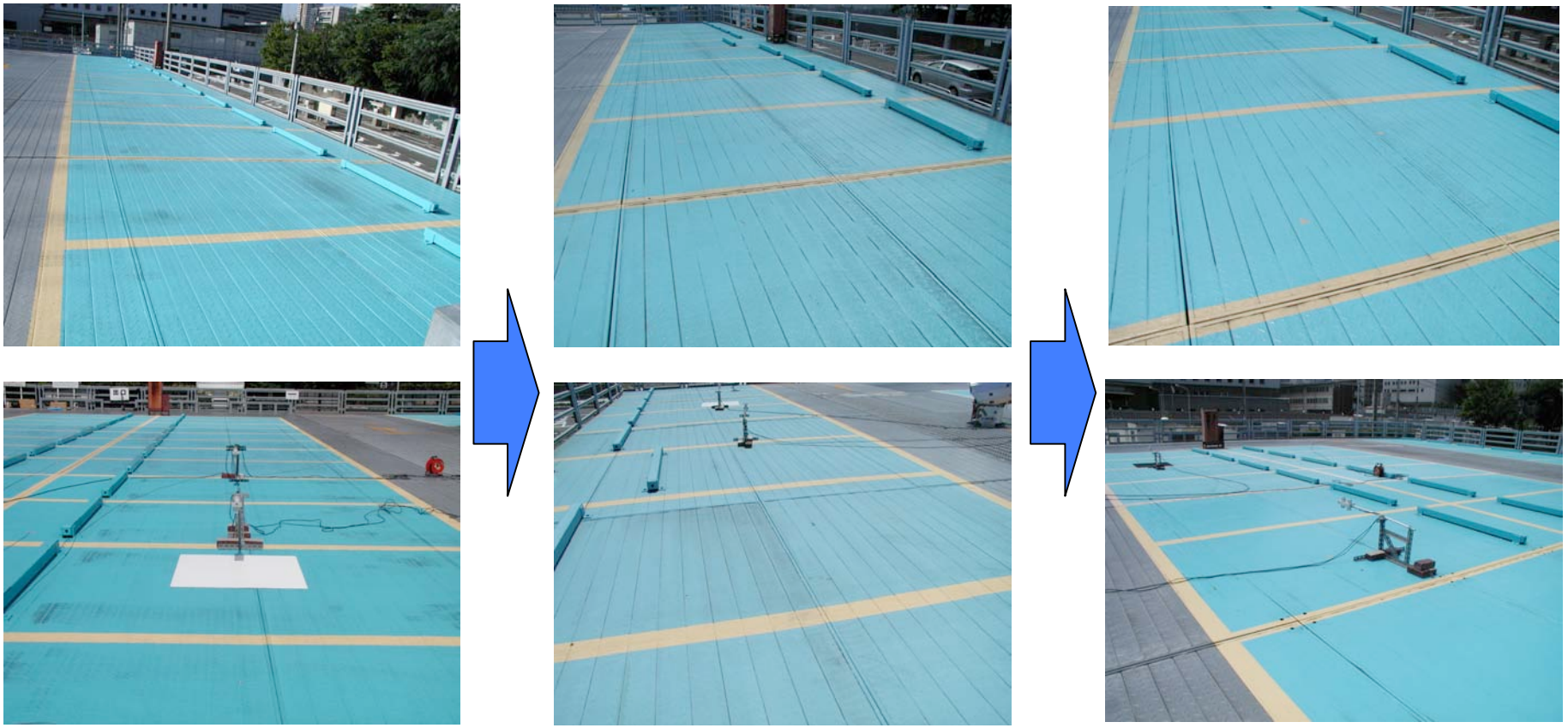
Effect of global insolation on instantaneous apparent solar reflectance



Effect of data selection with threshold of insolation on solar reflectance

- Solar reflectances of several cool paint surfaces become higher by the data processing.
- The difference between methods of measurement is small.

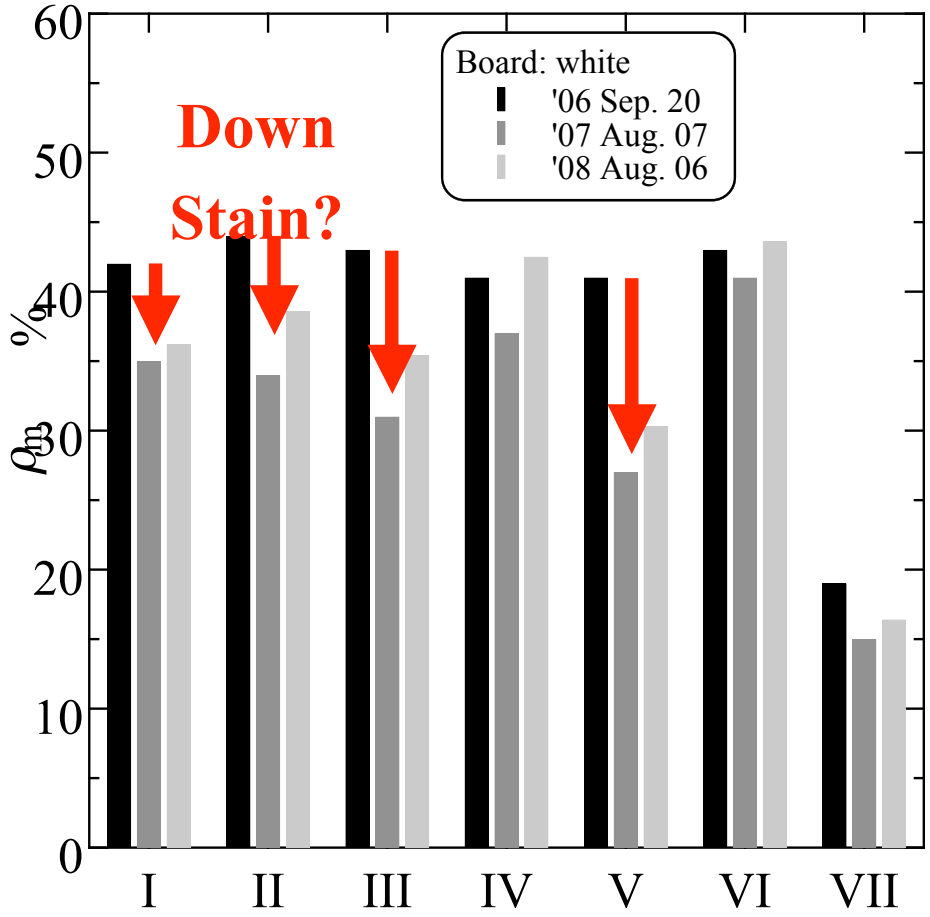
Evaluation of Aged deterioration of painted surfaces



2006.9.20 2007.8.7 2008.8.6

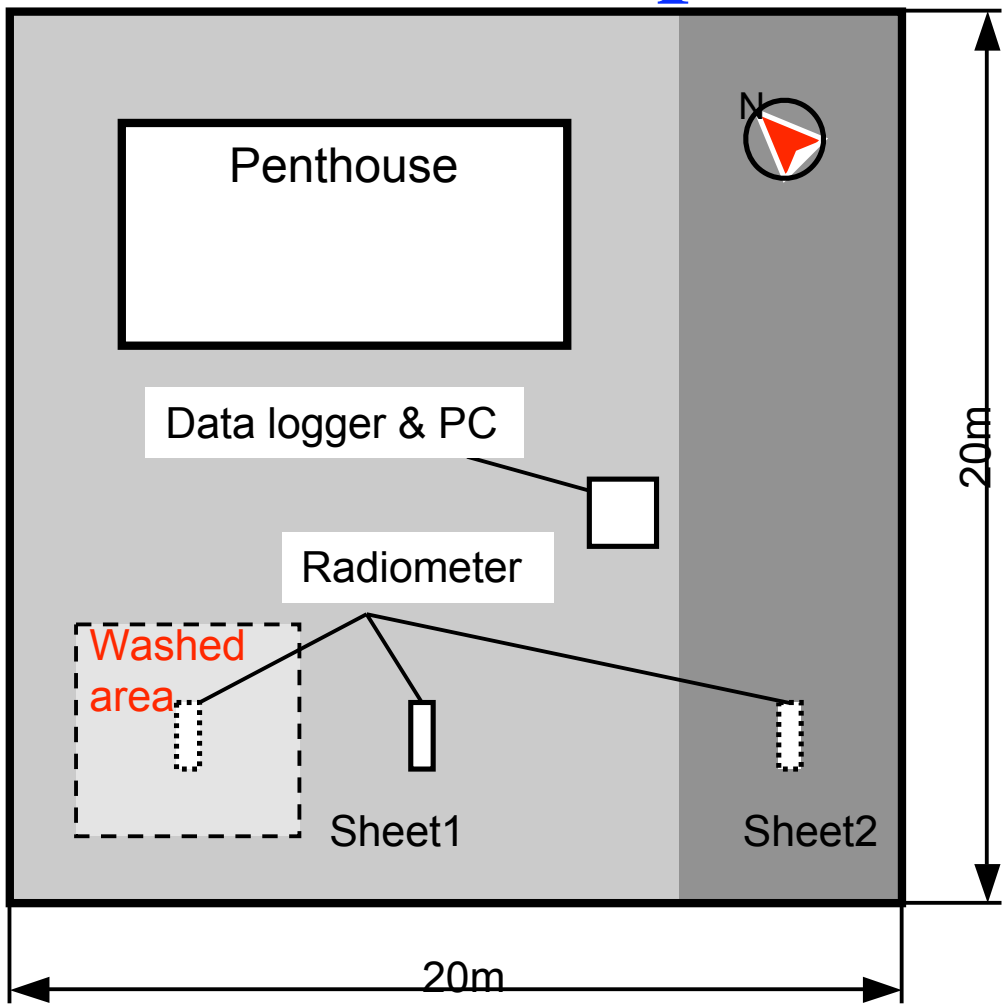
- Similar measurement are also performed every one year since execution of painting.

Evaluation of Aged Deterioration



- In the cool paint surface except IV and VI, remarkable aged deterioration is found between the results of 2006 and 2007.
- Compared between the results of 2007 and 2008, the change of solar reflectance during the period is smaller than that from 2006 to 2007.

Measurement Site (2):
Cool Waterproof Sheet



Outline of Measurement Site
(Rooftop surface)

Measured site

Measurement situation（N→S）

Measured dates
Feb. and Aug. 2007,
Aug. 2008 (A square area in Sheet 1 is washed with neutral detergent.)

Measured Results (2)

Solar reflectance of waterproof sheets in each measuring condition

Object	Method	Solar reflectance (%) 1st Feb. 6 2007	2nd Aug. 9 2007	3rd Aug. 7 2008
Sheet1 (unwashed)	White	59.8	44.9	42.1
	Black	59.1	43.4	43.7
	2 point correction	59.3	---	42.9
Sheet1 (washed)	White	---	---	54.0
	Black	---	---	55.2
Sheet2 (unwashed)	White	40.3	24.9	25.8
	Black	37.4	27.1	27.2

- Solar reflectance significantly decreases for a half year from execution, but it hardly changes in the next one year.
- The solar reflectance of Sheet1 is restored to around the original value of execution by washing.

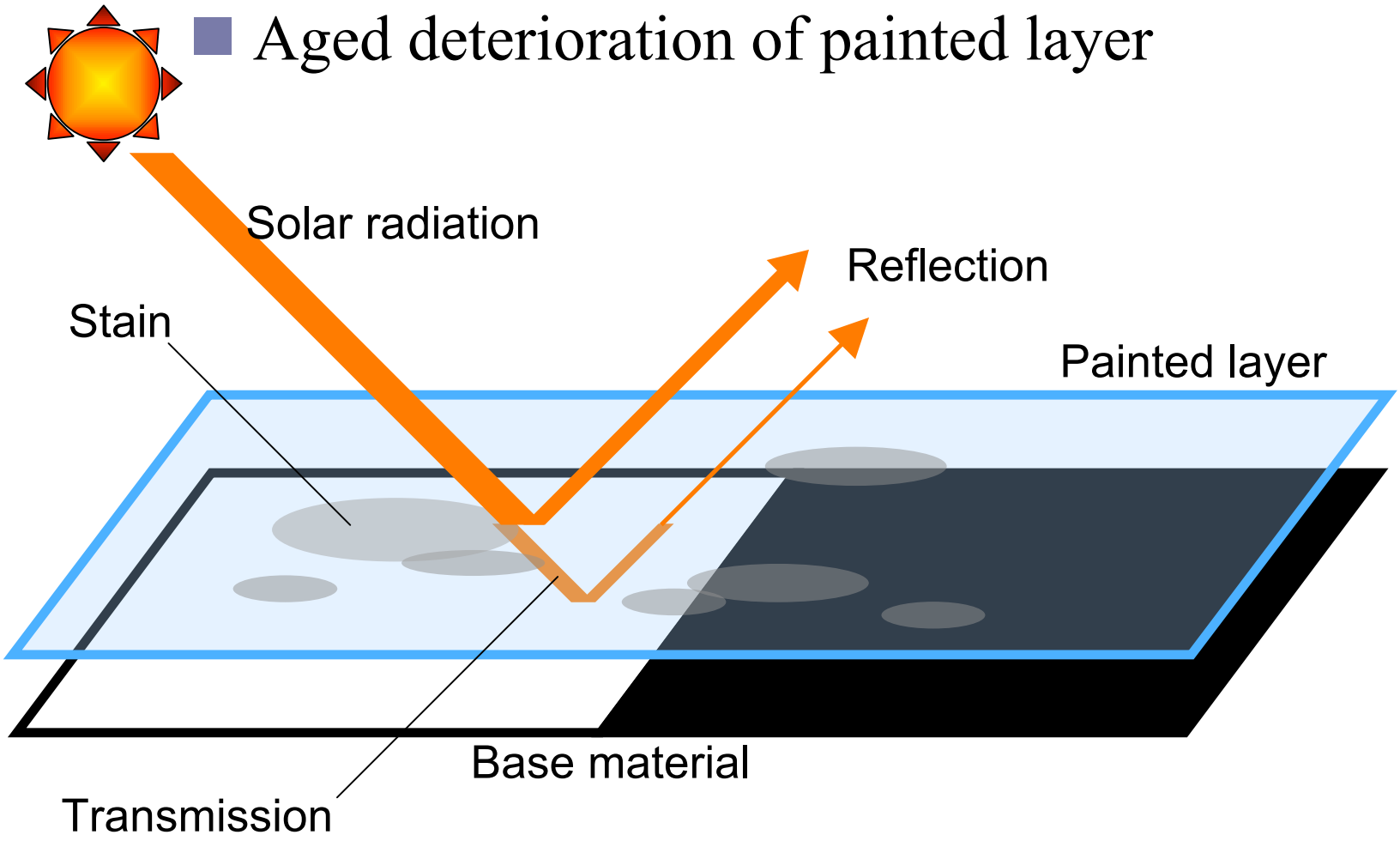
The decrease of solar reflectance is caused by the effect of deposited stain.

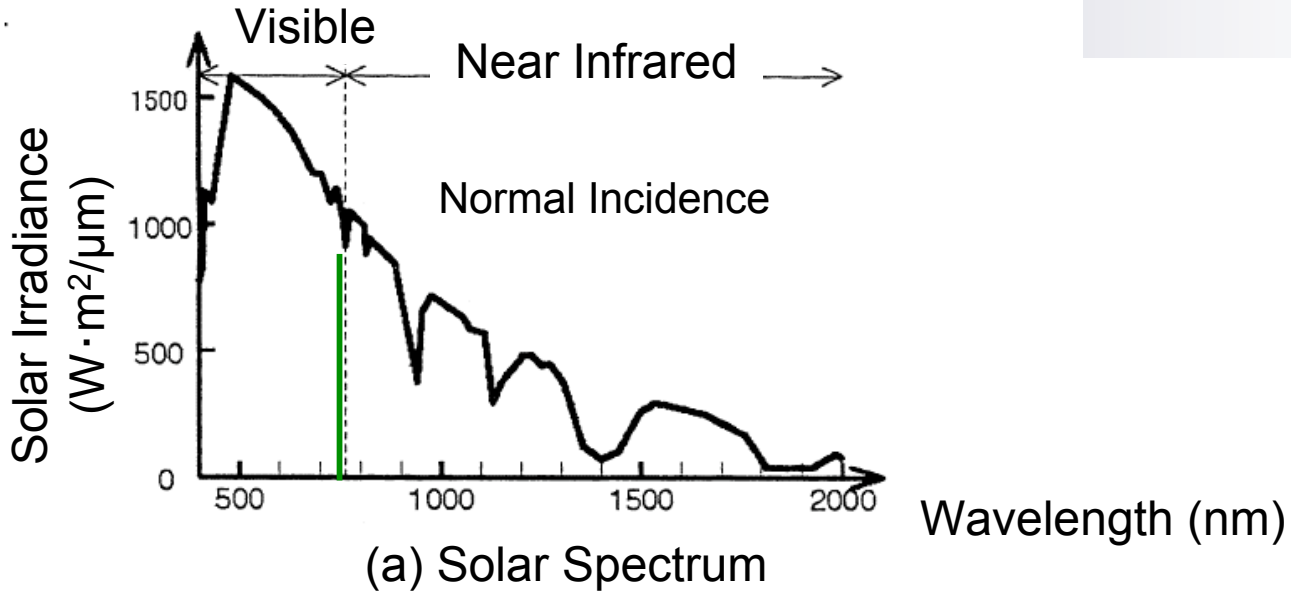
Summary

- On-site measurements of solar reflectance for cool painting and water proof sheet can be performed by use of standard reference board.
- The precision of reflectance measurement is estimated as ±1.5%.
- The solar incident angle less than 40 degree is preferable as the measurement condition.
- The aged deterioration calms down in more than one year after execution, and the reflectance performance becomes stable. In addition, the solar reflectance can be restored to around the original value of execution by washing stain on the surface.

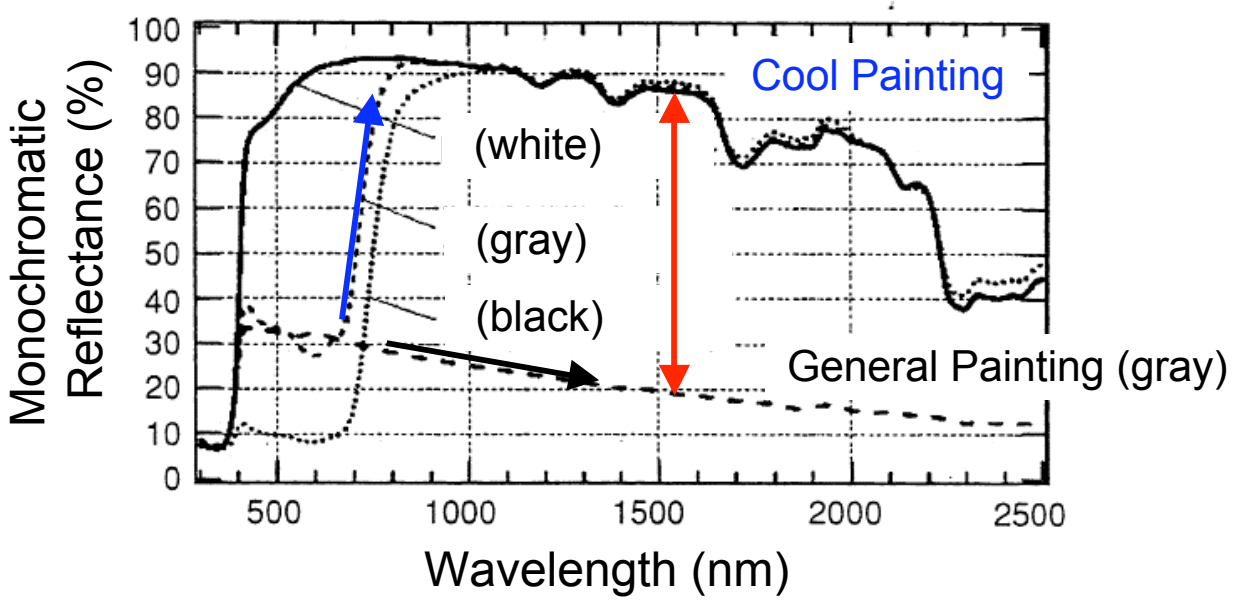
Need for on-site measurement of radiative properties

- Transmission from base material (Coating state)
- Stain on surface
- Aged deterioration of painted layer





(a) Solar Spectrum



(b) Reflectance Spectrum of Cool Painting

Measurement Date & Condition

Date : Sep. 20 & Oct. 12 (2006)

Height : 40cm, 50cm & 70cm

No.	Date	Plate color	Height (cm)
1	Sep. 20	white	50
2	Sep. 20	white	70
3	Oct. 12(1)	white	40
4	Oct. 12(2)	white	40
5	Oct. 12(2)	black	40

Measurement Date & Condition

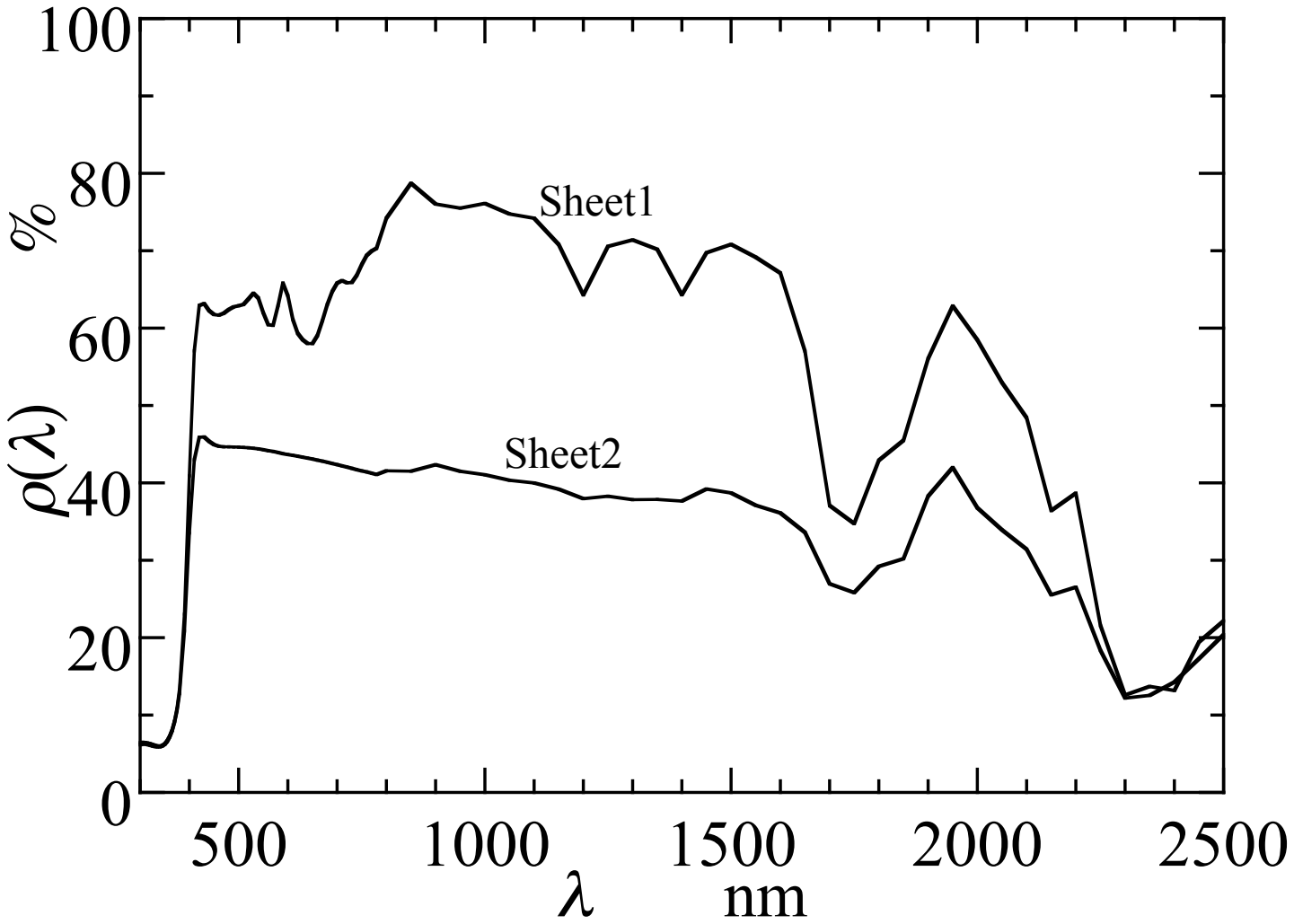
Date : Feb. 6 & Aug. 9 (2007)

Item : Total Solar Reflectance
& Infrared Emiitance

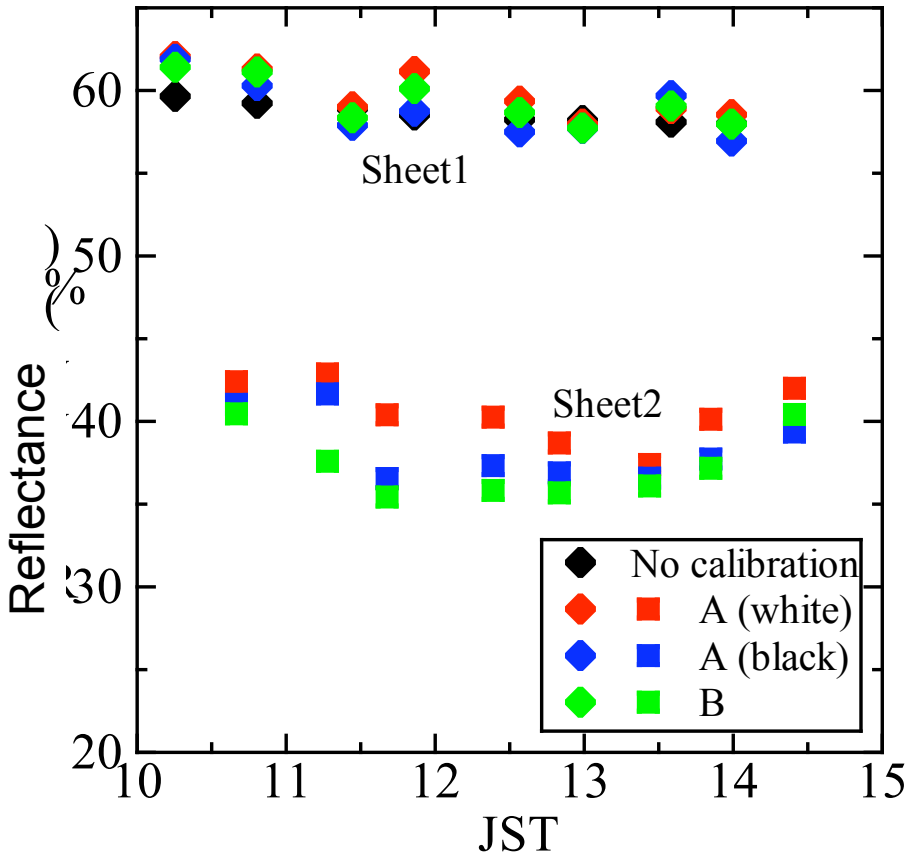
Height : 40cm

Standard Plate : white, black, without

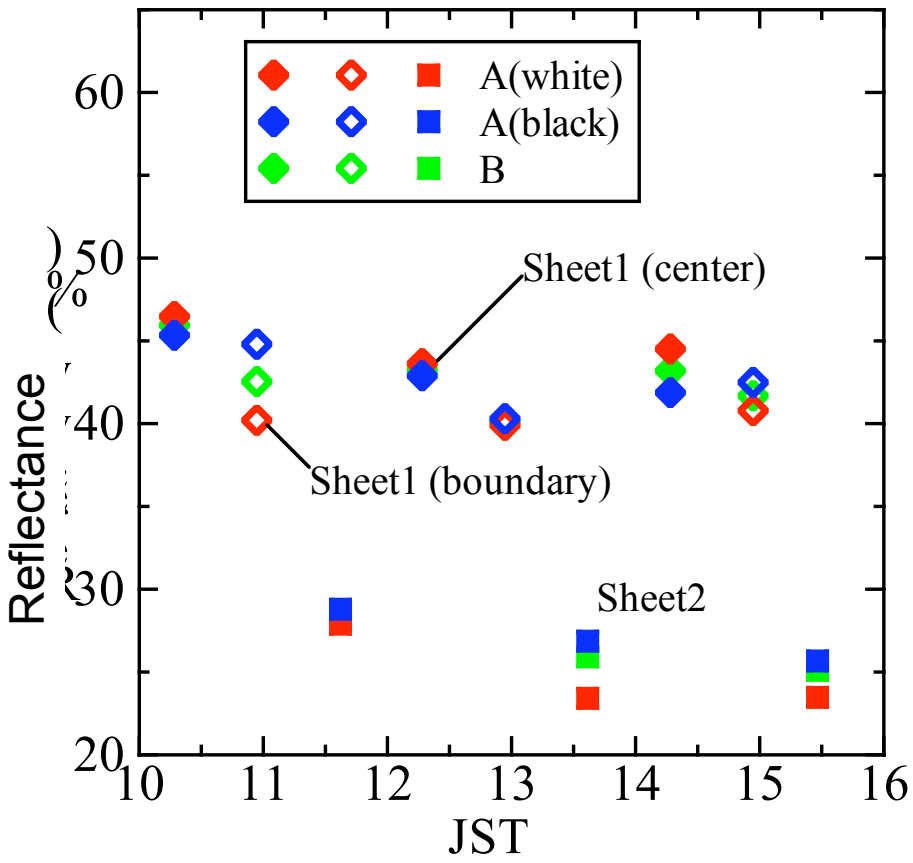
Sampling : 10 min. per 20 seconds


100
80
60
40
20
0
%
ρ(λ)
Sheet1
Sheet2
500
1000
1500
2000
2500
λ
nm

Measured Results (2) Solar Reflectance



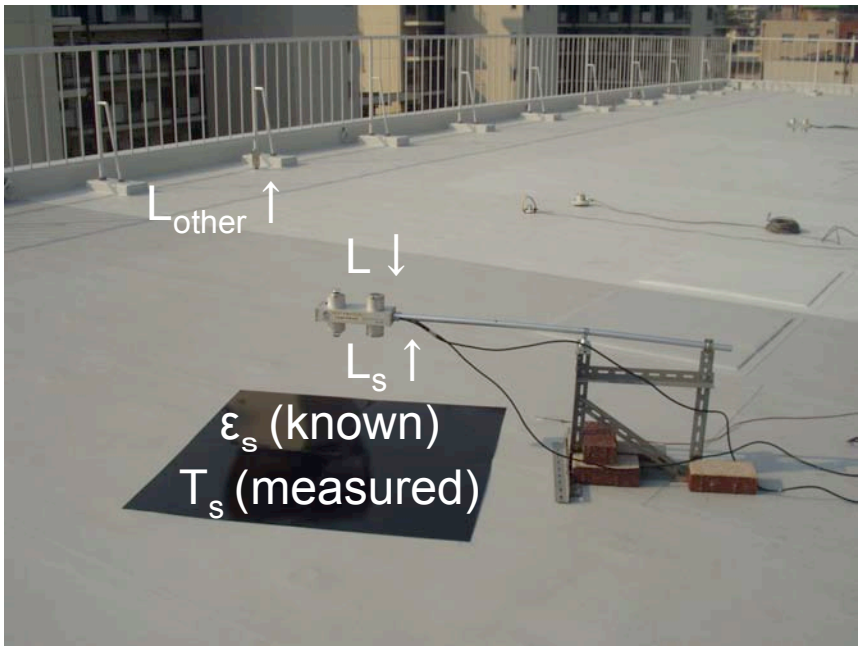
Feb. 6 (2007)

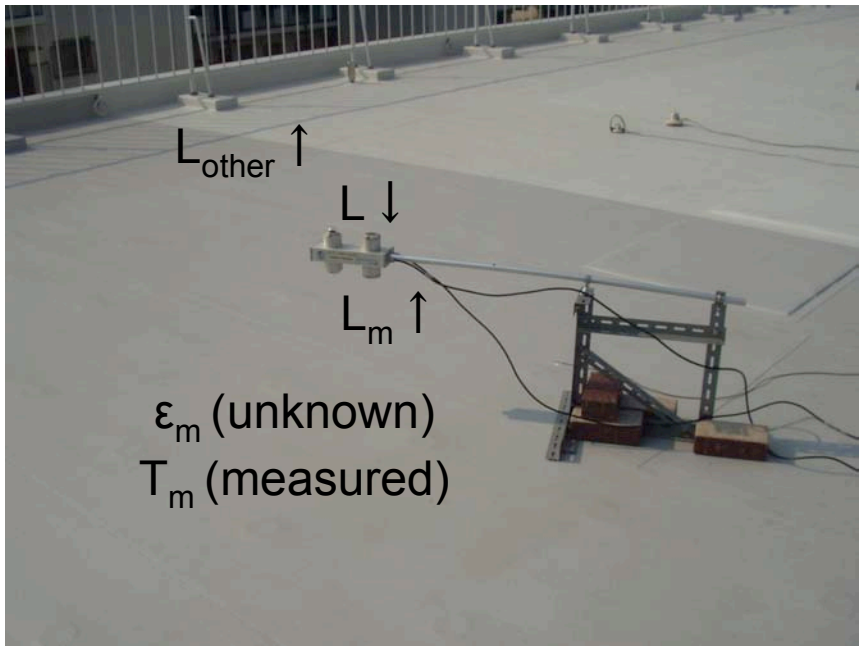


Aug. 9 (2007)

Measurement Method of Infrared Emittance

Narrow Measured Surface





$$\begin{cases} L_s\uparrow = (\varepsilon_s\sigma T_s^4+(1-\varepsilon_s)\,L\downarrow)\times\varphi+L_{other}\uparrow\times(1-\varphi) \\ L_m\uparrow = (\varepsilon_m\sigma T_m^4+(1-\varepsilon_m)\,L\downarrow)\times\varphi+L_{other}\uparrow\times(1-\varphi) \end{cases}$$

$$\varepsilon_m = \cdots$$

JIS R 3106

「Measurement Method of Transmittance, Reflectance and Emittance of Plate Glass」

Monochromatic reflectance spectrum from 300 to 2100 nm is measured by spectrometer with integrated sphere. Solar reflectance is obtained from the measured data multiplied by weight factors. The incident angle is less than 15 degree.